OZONE EMISSION OF PHOTOCOPIERS FROM SELECTED GOVERNMENT AGENCIES

A Research Paper Presented to
The Faculty of
Philippine Science High School Western Visayas
Bitoon, Jaro, Iloilo City

In Partial fulfillment
Of the Requirements in
SCIENCE RESEARCH 2

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April 2010

This research paper hereto entitled:

"Ozone Emission of Photocopiers from Selected Government Agencies"

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Four - Photon

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ABSTRACT

Ozone emission could trigger irritation of the respiratory system, coughing, throat irritation, and an uncomfortable sensation in the chest. Indoor ozone comes from different anthropogenic sources such as copying machines, laser printers, electrostatic air filters and ozone generators. Ozone forms during copying when a photoreceptor and paper are inserted or discharged as well as when UV lamp operates during photocopying (Valuntaite and Girgzdiene 2007). This study aimed to measure amount of ozone using the Schoenbein Paper method. Specifically, it aimed to: a.) Measure the amount of ozone concentration (in parts per billion) emitted by photocopiers, b.) Compare the amount of ozone concentration detected among the four sites: Tigbauan Municipal Hall, Land Transportation Office, Department of Science and Technology Regional Office and the Philippine Science High School copying room. Schoenbein Paper Method was used to measure the amount of ozone emission from four agency sites. Paper strips were coated in a mixture of potassium iodide, distilled water and cornstarch, dried under the oven, and then exposed on the site for 8-hr period. The ozone concentrations were then quantified using the Relative Humidity Schoenbein Number Chart through the recorded color change and relative humidity. The results showed that there was a tolerable concentration of ozone present in the testing sites. The ozone concentrations were recorded in Tigbauan Municipal Hall (7.07ppb), LTFRB (6.33ppb), PSHS-WV (6.03ppb), and DOST VI (5.67ppb). It was confirmed that the amount of ozone emitted from the photocopiers were not harmful to humans.

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Chapter 1

INTRODUCTION

A. Background of the Study

Ozone is a colorless, pungent gas and is considered as a secondary pollutant. It is composed of three oxygen atoms. Ozone is a highly reactive, unstable and toxic gas. It is a gas that can form and react under the action of light and is present in two layers of the atmosphere: the stratosphere and the troposphere (Schoeberl 1999).

Ozone is an unstable molecule produced from elemental oxygen, often called an allotropic form of oxygen. The overall reaction for ozone formation is described by an endothermic reaction: $3O_2 \leftrightarrow 2O_3$ (Ho at 1 atm = +284.5kJ/mol). It occurs naturally in small amounts in the earth's stratosphere, where it serves as protection between harmful UV rays (Schoeberl 1999).

Ozone can be quite hazardous when found in the troposphere. In the lower atmosphere (troposphere), ozone is the most important photochemical oxidant. There, it is a secondary pollutant formed when precursor pollutants such as nitrogen oxides (NO_x) and volatile organic compounds react under the action of light (Anonymous 2005).

Ozone can cause irritation of the eyes, the upper respiratory tract, throat and nasal passages if its concentration reaches 0.25 ppm (parts-per-million) or above. Other symptoms include headache, shortness of breath, dizziness, general fatigue and temporary loss of olfactory sensation. A level of 10 ppm is immediately dangerous to life and health.

Copying machines, laser printers, electrostatic air filters, ozone generators and other electric devices that produce ozone are the main anthropogenic sources of ozone emission in rooms. It was established that an average concentration of ozone at the level of a copying machine was 185+56 μg/m^3, and near the ceiling and ground – 55+4 μg/m^3 and 13+15 μg/m^3, respectively. Some authorities suggest that a concentration of 0.1 ppm might have the effect of causing premature ageing and shortened life span (Valuntaite and Girgzdiene 2007).

Photocopiers operate by reflecting light from the original item so that an image is projected onto a photoreceptor, which is an electrically charged drum or belt. The surface of the drum is photosensitive; it loses the electrostatic charge when exposed to light. Reflected light produces a pattern of charges on the drum or belt and leaves a latent image. The electrostatic charge attracts the toner and reproduces the image permanently onto the paper by heat and pressure (Valuntaite and Girgzdiene 2007).

Ozone forms during copying when a photoreceptor and paper are inserted or discharged as well as when UV lamp operates during photocopying (Valuntaitė and Girgždienė, 2007). It creates ozone through their "corona wires" that apply a charge to the paper so the ink will cling to it (www.aerias.org).

The study aimed to determine the ozone emissions from the photocopying machines and the amount of ozone using the Schoenbein Paper method.

B. Statement of the Problem

This study aimed to measure amount of ozone emitted by photocopying machines found in Tigbauan Municipal Hall, Land Transportation Office, Department of Science and Technology Regional Office and the Philippine Science High School copying room using the Schoenbein Paper Method.

C. Objectives of the Study

This study specifically aimed to:

1. Measure the amount of ozone concentration (in parts per billion) emitted by photocopiers using the Schoenbein Paper Method.

2. Compare the amount of ozone concentration detected among the four sites.

D. Significance of the Study

Ozone can cause numerous health effects. It interferes with lung function and can cause pain and discomfort at concentrations as low at 0.08 ppm. Ozone exposure can also reduce resistance to infections. Research has shown that immune system cells move into the lungs after acute exposure to ozone, producing a nine-fold increase in disease fighting cells. In addition, short-term ozone exposure has also been shown to decrease resistance to bacterial pneumonia in animal studies (www.vcapcd.org).

If the amount of ozone detected reaches or goes beyond the maximum allowable level (0.075 ppm for the 8-hr period), it can be deduced that photocopiers emit ozone in a quantity where it is no longer acceptable in a working environment. Safety measures can then be implemented for the safety of the workers and of the people near the area where there are photocopiers. This is also for acknowledging others about the effects of ozone emission and its prevention.

E. Scope and Delimitations

This study used the Schoenbein Paper method to determine the amount of ozone of the four different sites. It was adopted from the study of Valuntaite and Girgzdiene. One of the delimitations of this study is the Schoenbein color chart. The color determined in the Schoenbein paper is not accurate due to many factors such as temperature, surroundings and etc. The method is based on the color change scheme so certain errors may occur. Also, exposure to sunlight of the paper used during the experiment may alter the results and may contribute errors.

F. Definition of Terms

Mixture - a solution of distilled water, cornstarch and potassium iodide.

- a combination of two or more substances that are not chemically united and do not exist in fixed proportions to each other (Ophardt, 2003)

Schoenbein Color Chart - a color chart used as the basis for the color changes in the Schoenbein paper

-

Schoenbein Number – it is the number that corresponds to the Schoenbein Color Chart.

Schoenbein Paper – the paper used for detection of ozone from an area.

Relative Humidity – the percentage of water vapor in air

Relative Humidity Schoenbein Number Chart – the chart used in determining the gathered ozone concentration using the Schoenbein number and the relative humidity values.

Chapter 2

REVIEW OF RELATED LITERATURE

A. Ozone

A.1 Physical and Chemical Properties of Ozone

Ozone is an allotropic form of oxygen. The ozone molecule, which has a molecular weight of 48, is made up of three oxygen atoms bound by equal oxygen-oxygen bonds. This structure is inherently unstable and is the reason for ozone's powerful oxidizing ability. It is 1.7 times heavier than air and about 13 times more soluble than oxygen in water at standard temperature and pressure (Loeb 2008).

Ozone has a sweet, clover-like odor at low concentrations, but it becomes pungent, with an odor detection limit of about 0.02 ppm, at higher concentrations. It is a bluish gas, but at concentration at which it is generated for normal use, this color is not noticeable. Ozone condenses into a dark blue liquid that explodes easily at -169°F (-117.67°C).

Under normal conditions, the half-life of ozone indoors is between seven and 10 minutes and is determined primarily by surface removal and air exchange. Other investigation showed that ozone half-life in a standard office is less than 10 min (Valuntaite and Girgzdiene 2007).

Ozone occurs both in the earth's upper atmosphere and at ground level.

A.2 Formation of Ozone

A.2.1 Stratospheric Ozone

Most of the ozone, specifically 90% of atmospheric ozone, can be found in a layer between 10 and 60 km above the earth's surface. This ozone located in the stratosphere is known as the ozone layer. In this region, ozone removes most of the biologically harmful ultraviolet light before the light reaches the surface, and it plays an essential role in setting up the temperature structure and therefore the radiative heating or cooling balance in the atmosphere (Schoeberl 1999).

Ozone is produced by the photolysis of molecular oxygen, O_2. This photolysis of ozone in the stratosphere is the process by which most of the biologically damaging ultraviolet sunlight (UV-B) is filtered out. The oxygen atom, O, produced by this photolysis recombines with O_2 to form ozone, O_3. Ozone formation primarily occurs in the tropical upper stratosphere, where it is transported poleward and downward by the large-scale Brewer-Dobson circulation.

Brewer-Dobson Circulation is a circulation pattern that sets up between equator and pole in the winter hemisphere. Air is lifted out of the tropics from the troposphere to the stratosphere, where it acquires high ozone content in the photochemical source region of the tropical stratosphere. Next, this high-ozone moves poleward and downward, descending into the middle latitudes upper troposphere and polar latitudes lower stratosphere. It is the reason for the observed column ozone distribution which is low in the tropics and high in the polar regions.

The overall reaction of ozone formation is described by an endothermic reaction:

$$3O_2 \leftrightarrow 2O_3 \ (\Delta Ho \text{ at } 1 \text{ atm} = +284.5 \text{ kJ/mol})$$

The formation of ozone by the photolysis of molecular oxygen removes most of the incident sunlight with wavelengths shorter than 200nm. The wavelengths between 200 and 310nm are removed by the photolysis of ozone itself (Schoeberl 1999).

A.2.2 Tropospheric Ozone

Tropospheric ozone is a secondary air pollutant, changes in the ambient of which are affected by both the mission rates of primary pollutants and the variability of meteorological conditions (Skacel and others 2008). About 10% of the atmospheric ozone can be found in the troposphere. Ozone is formed when pollutants emitted by cars, power plants, chemical plants, and other sources react chemically in the presence of sunlight (Schoeberl 1999; Agrawal 2007).

Ozone formation in a polluted environment outside is mainly caused by photochemical reactions between volatile organic compounds (VOCs) and nitrogen oxides NOx:

NOx +VOC + hυ→O3+ B, where B – other compounds; *hv* –light quantum

In addition to the presence of VOCs and nitrogen oxides, there are other factors which contribute to the formation of ground-level ozone, such as solar insulation, cloud cover, high temperature, wind directions, low wind speeds, low levels of precipitation and positions of fonts.

Small amounts of ozone develop naturally, especially during lightning storms. Ozone is the main component of photochemical smog.

Photochemical smog is a mixture of pollutants that are formed when nitrogen oxides and VOCs react to sunlight. The main visible effect is the brown haze that can be seen above many cities. The brown tinge is caused by very small liquid and solid particles scattering the light (EPA Information 2004).

A.2.2.1 Anthropogenic Sources of Ozone

Copying machines, laser printers, electrostatic air filters, ozone generators and other electric devices that produces ozone are the main anthropogenic sources of ozone emission in rooms. Ozone also forms from ultraviolet (UV) radiation sources (for example, in order to ensure sterility bactericide UV lamps are frequently used in hospitals, labs, food, and industry).

Commercial ozone generators are advertised to remove airborne contaminants and improve indoor environments. This controversial equipment can also be attributed as sources of ozone in a room Environment Protection Agency (USA) pronounced that this equipment is not sufficiently effective in extermination of contaminants in the air (Valuntaite and Girgzdiene 2007).

Ozone forms during copying when a photoreceptor and paper are inserted or discharged as well as when UV lamp operates during photocopying. Since various photocopying processes produce ozone, manufacturers incorporate some type of filtration system to reduce the amount of ozone to the surrounding air. Investigations show that ozone emission can increase between periods of routine maintenance (Valuntaite and Girgzdiene 2007).

Concentration of ozone in the room depends on concentration of ozone outside. Proportion of these concentrations depends on many factors such as air infiltration or air exchange between environment levels, circulation of air in the room, structure of room surfaces, and ozone reaction with other chemical compounds. Furthermore, this proportion varies during the day and is not steady in different days and also depends on the season (Valuntaite and Girzdiene 2007).

The study established that ozone concentration increases with the increase of the copying process intensity in an office room. Average concentration of ozone at the level o a copying machine was 185+56 μg/m^3, and near the ceiling and ground – 55+4 μg/m^3 and 13+15 μg/m^3, respectively. The use of ventilator reduces an average ozone concentration near the source up to 50 μg/m^3, from 280+63 μg/m^3 to 235+52 μg/m^3 (Valuntaite and Girgzdiene 2007).

The amount of ozone above any given spot of Earth is infrequently constant. Consider the diurnal or daily ozone cycle over Albuquerque, New Mexico. Early on a July morning at the base of the Sandia Mountain aerial tramway just northeast of the city, considering ground-level ozone concentration might reaches 20-30 ppb. As the sun rises in the sky, photochemical ozone production increases, especially when the wind is from the southwest and the clean mountain air is spiked with nitrogen oxides and hydrocarbons from automobile exhaust. Although little or no photochemical smog may be visible, the ozone concentrations might reach 40-60 ppb by late afternoon. As the sun sinks behind the volcano cinder cones west of Albuquerque, the ozone level also falls. Later that evening, the ozone returns to its normal "background" level.

A.3 Effects of Ozone

High indoor concentrations can cause respiratory failure, hacking cough, pain during deep breath, gnawing in the breast and sometimes even nausea (Valuntaite and Girgzdiene 2007).

In copying machines, it was established that at 0.5m distance from copying machine ozone concentration decreases twice, therefore, a person working with a copying machine should be at far enough distance from the ozone source to reduce its effect on health. The recommended maximum exposure is an eight hour time weighted average exposure to ozone of 0.1 ppm (0.2 $\mu g/m^3$) (Valuntaite and Girgzdiene 2007).

The ground-level ozone is considered harmless to vegetation if its concentration does not exceed 60$\mu g/m^3$. Investigations carried out in Lithuania show that concentration of ozone in the atmosphere exceeds 100$\mu g/m^3$ about 9% of the time.

Ozone can also damage various compounds. It can cause the cracking of rubber and paint, reduction in the tensile strength of textiles, and the fading of dyed fabric (Fadeyi 2009).

B. Measuring Tropospheric Ozone

Several ways to measure tropospheric ozone are performed nowadays. It changes the color of some chemical compounds and solutions since it is a strong oxidizer. For instance, paper soaked in a mixture of starch and potassium iodide will change color when exposed to ozone.

The reaction of ozone with various chemicals, gases, and even some lubricating oils causes a faint luminescence that can be detected by a sensitive photomultiplier tube. Detection systems such as this are identified as chemiluminescence detectors.

Since ozone absorbs ultraviolet radiation so effectively, many kinds of ozone detectors incorporate a UV lamp and a detector. Air is passed through a chamber, and any attenuation is assumed to have been caused by ozone. A problem with this method is that attenuation can also be caused by dust. Therefore, it's common practice to use two chambers, one of which receives air from which any ozone has been scrubbed by a catalytic converter. Alternatively, scrubbed and unscrubbed air can be passed in sequence through the same chamber. Either way, the error caused by dust and other contaminants in the ozone-free sample can then be determined by subtraction.

Sulfur dioxide and other chemicals can interfere with the chemical and UV detection of ozone. When scientists at the Montsouris observatory near Paris became aware of this problem in 1905, they built a second chemical ozone detector. The air inlet for the new detector was fitted with a 4-meter (13-feet) hose of natural rubber, which completely destroyed any ozone passing through it. In this way any errors in the original detector caused by gases other than ozone could be eliminated.

B.1. Schoenbein Paper Method

Schoenbein Paper tests for the presence of ozone in the air that was first developed by Christian Friedrich Schoenbein, who also discovered ozone (teachers.sduhsd.k12.ca.us). This paper is coated with a mixture of water, starch and potassium iodide. When exposed to air, the following chemical reaction takes place:

$$2KI + O_3 + H_2O \longrightarrow 2KOH + O_2 + I_2$$

When ozone is present in air, it will oxidize the potassium iodide on the Schoenbein paper that produces iodine. The resulting product, iodine, reacts with starch, producing a purple or brownish color. The shade of color on the Schoenbein paper reflects the amount of ozone present in the environment. The resulting color change is then compared to the Schoenbein Color Chart, which is used to obtain the Schoenbein Number.

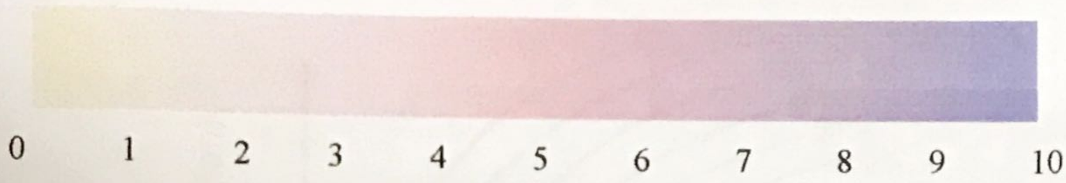

Figure 1. Schoenbein Color Scale

0-3	Little or no change
4-6	Lavender hue
7-10	Blue or purple

Table 1. Schoenbein Number

Relative humidity of the data collection site is determined by using a bulb psychrometer or local weather data. Air temperature and the dew point temperature are also measured. These two values are used to obtain the relative humidity.

The relative humidity is rounded off to the nearest 10 percent. High relative humidity makes the paper more sensitive to ozone, and a higher Schoenbein number is observed. To correct for this, the relative humidity must be determined and figured into the calculation of ozone concentration. The Schoenbein number is then used to obtain the ozone concentration, using the Relative Humidity Schoenbein Number Chart. The Schoenbein Number is plotted on the x-axis, and then traced up to the average humidity closest to the recorded relative humidity on the chart. Then that point is traced towards the y-axis, where it would give the approximate ozone concentration recorded.

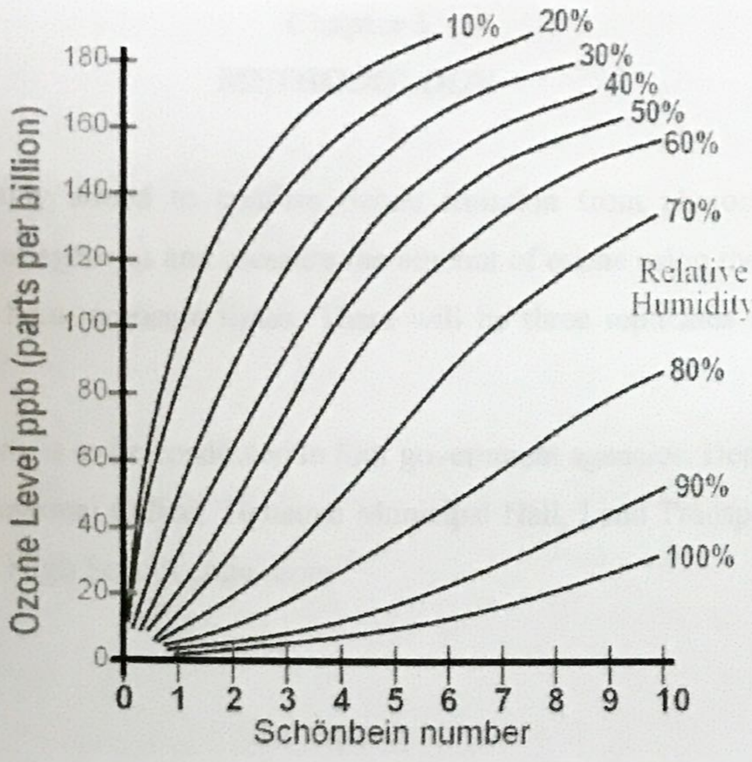

Figure 2. Relative Humidity Schoenbein Number Chart

Humidity and sunlight are factors that can affect the feasibility of the test. High humidity and direct sunlight causes the Schoenbein paper to speed up its reaction, resulting in darker color. The paper is sensitive to the rays of sun or any form of light.

Chapter 3
METHODOLOGY

This study aimed to confirm ozone emission from photocopying units from selected government agencies and measure the amount of ozone using the Schoenbein Paper method, under 8- hour exposure times. There will be three replicates for every exposure period.

The study is to be conducted in four government agencies: Department of Science and Technology Regional Office, Tigbauan Municipal Hall, Land Transportation Office and Philippine Science High School copy room.

A. List of Materials

Distilled water	Thermometer	250 mL beaker
Corn starch	Plastic zip-lock bags	Stirring rod
Potassium iodide, KI	string	Top-load Balance
Hotplate	Spray bottle	Modified metal tray
2.5" x 1.5" Filter papers	Oven	cotton or wet cloth

B. Procedures

B.1 Preparation of Schoenbein Paper

One hundred milliliters of distilled water was measured and was placed in a 250 mL beaker, and then 10.0 grams of cornstarch was added. While being stirred, 0.5 g of potassium iodide was added to the mixture. The resulting mixture was then heated on a hotplate (medium setting), preheated at a high setting for five minutes. The mixture was removed from heat when it formed a translucent gel, and was set aside to allow cooling.

After the mixture has cooled, it was used to coat the filter paper strips. The filter paper strips were then dried in the oven. The paper strips are sensitive to light, and therefore should never be exposed to direct light, and only exposed to indirect light when placed out for sampling.

B.2 Recording Relative Humidity

Relative Air Humidity was quantified using the dry and wet bulb temperatures. The dry bulb temperature (T_{db}) can be measured with a thermometer. The wet bulb temperature was measured with a standard thermometer with wet cotton around the bulb. Continuous air flow was maintained since it is important to evaporate water from the wet cotton and achieve a correct wet bulb temperature. This sufficient air movement was achieved by swinging motions of the hand.

Relative humidity can then be estimated using the following tables:

Temperature in Celsius

Relative Humidity - *RH* (%)

Difference Between Dry Bulb and Wet Bulb Temperatures $T_{db} - T_{wb}$ (°C)	Dry Bulb Temperature - T_{db} (°C) 15	18	20	22	25	27	30	33
1	90	91	91	92	92	92	93	93
2	80	82	83	84	85	85	86	87
3	71	73	75	76	77	78	79	80
4	62	65	67	68	70	71	73	74
5	53	57	59	61	64	65	67	69
6	44	49	52	54	57	59	61	63
7	36	42	45	47	51	53	55	58
8	28	34	38	41	45	47	50	53
9	21	27	31	34	39	41	45	48
10	13	20	25	28	33	36	40	43

Table 2. Relative Humidity Chart

Because relative humidity affects results, Schoenbein paper should not be left outside during periods of high humidity especially during rain.

B.3. Testing

For the on-site testing of ozone concentration, ten pieces of Schoenbein filter paper strips were sprayed with distilled water and suspended at the testing site, directly above the photocopying units and away from sunlight. Paper strips were collected after 8-hour exposure times, the average working hours of employees in the government agency. The paper changes color when ozone is present, since ozone causes iodide to oxidize into iodine.

The paper strips were then placed inside a sealable, airtight container. Color change was then recorded by being compared to the standard Schoenbein Color Chart. The values of humidity and ozone concentration were quantified using the Relative Humidity Schoenbein Number Chart.

B.4. Relative Humidity/Schoenbein Number Chart

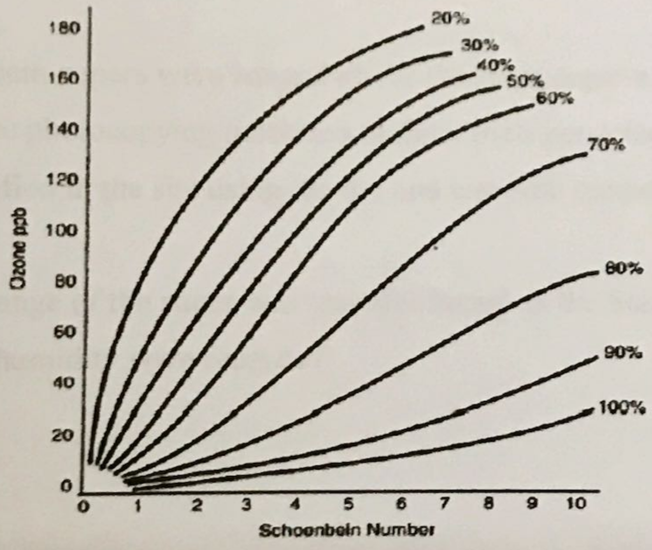

Figure 3. Schoenbein Number Chart

The Schoenbein Number obtained from the comparison of the color change in the paper with the Schoenbein Color Chart will be needed, along with the Relative Humidity percentage in using the Schoenbein Number Chart. The values will be aligned and the corresponding ozone concentration (ppb) is found along the y-axis.

Chapter 4
RESULTS AND DISCUSSION

This study was conducted to determine the ozone concentration in the photocopying rooms of the selected government agencies, namely Tigbauan Municipal Hall, Land Transportation Office, Department of Science and Technology Regional Office and the Philippine Science High School copying room.

The study specifically aimed to a.) measure the amount of ozone concentration (in parts per billion) emitted by photocopiers, b.) compare the amount of ozone concentration detected among the four sites: Tigbauan Municipal Hall, Land Transportation Office, Department of Science and Technology Regional Office and the Philippine Science High School copying room.

The Schoenbein papers were hanged above the photocopiers. 10 replicates were exposed (eight hours) near the photocopying machines in three trials per selected sites. The relative humidity was quantified in the site using the dry and wet bulb temperatures.

The color change of the paper was recorded based on the Schoenbein Color Chart. Color change and relative humidity were recorded.

A. Results

The results confirmed that photocopiers emit ozone. The highest ozone concentration was recorded in Tigbauan Municipal Hall (7.07ppb), followed by LTFRB (6.33ppb), PSHS-WV (6.03ppb), and lowest recorded data in DOST VI (5.67ppb).

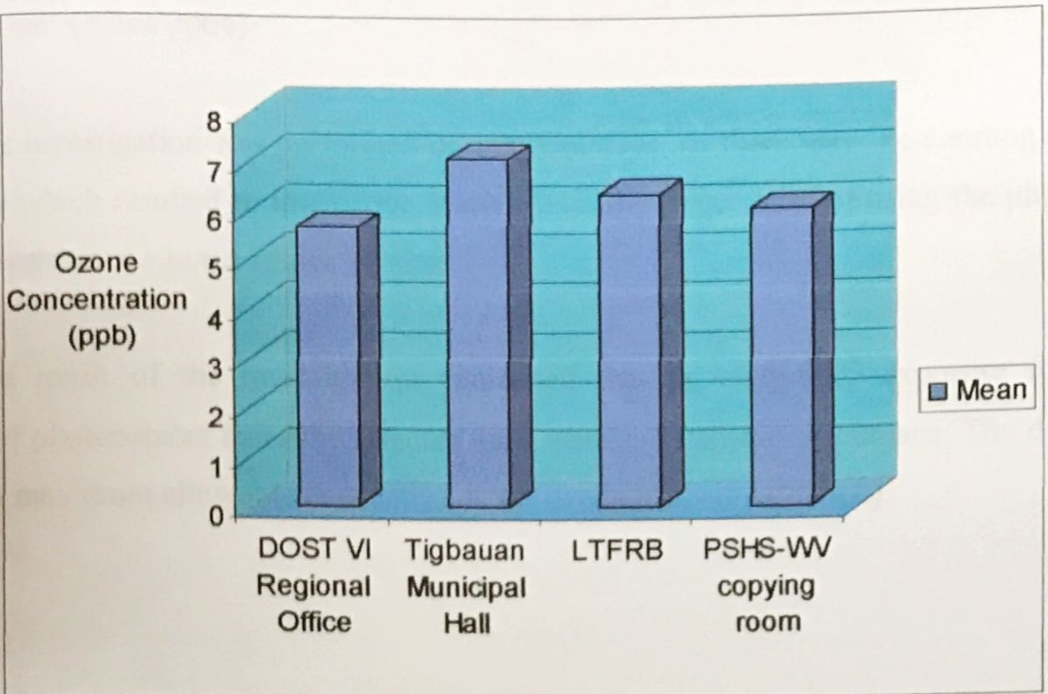

Figure 4. Ozone concentration from selected government agencies.

B. Discussion

The highest recorded ozone concentration was in Tigbauan Municipal Hall (7.07 ppb) and lowest recorded data in DOST VI (5.76ppb). However, the concentration of indoor ozone depends on a number of other factors, including the outdoor ozone concentration, air exchange rates, indoor emission rates, surface removal rates, reactions between ozone and other chemicals in the air, other anthropogenic sources of ozone, the presence and absence of ventilation and the frequency of using photocopiers (Weschler 2000).

The Tigbauan Municipal Hall is a well-ventilated and wide area. It has a mean relative humidity value of 78%. On the other hand, the DOST VI is also a well-ventilated but small area. It has a mean relative humidity value of 84%.

Ozone forms in the troposphere by the action of sunlight on certain chemicals (photochemistry). Chemicals participating in ozone formation include two groups of compounds: nitrogen oxides (NOx) and volatile organic compounds (VOCs). In general, an increase in temperature accelerates photochemical reaction rates. Scientists find a strong correlation between higher ozone levels and warmer days. With higher temperatures, we can expect a larger number of "bad ozone" (Allen 2004).

The investigation was performed during cool days, so there may be a strong correlation of the data which resulted to low ozone levels. Also, the frequencies of using the photocopying machines were scarce in the respected sites.

The result of the investigation confirmed that an eight-hour exposure from ozone emission of photocopiers from the selected sites were not harmful to humans. The data did not exceed the maximum allowable concentration for ozone exposure (75 pbb).

Chapter 5
SUMMARY, CONCLUSION AND RECOMMENDATIONS

A. Summary

This study aimed to confirm ozone emission from photocopiers and measure amount of ozone using the Schoenbein Paper method. Specifically, it aimed

1. To measure the amount of ozone (in parts per billion) emitted by photocopiers.

2. To compare the amount of ozone detected among the four sites: Tigbauan Municipal Hall, Land Transportation Office, Department of Science and Technology Regional Office and the Philippine Science High School copying room.

This study was able to establish the following findings:

1. It was confirmed that photocopiers emit ozone in the four selected sites (5.67 ppb, 7.07ppb, 6.33ppb and 6.03ppb respectively).

2. The highest ozone concentration was recorded in Tigbauan Municipal Hall and lowest in DOST VI.

3. It was also found out that changeable conditions such as presence or absence of ventilation, the use of other anthropogenic sources of ozone and frequency of use of photocopiers affect the recorded ozone concentration.

B. Conclusion

The results of the study confirmed that photocopiers from the selected sites emit ozone which is not harmful to humans.

Changeable conditions such as presence or absence of ventilation, the use of other anthropogenic sources of ozone and frequency of use of photocopiers affect the recorded ozone concentration.

C. Recommendations

It is recommended that further studies must be conducted in photocopying sites where many people are exposed. Also, thorough investigation of the comparative amount of ozone emission from different sources in a particular site would help out.

LITERATURE CITED

Agrawal M. 2007. Trend in tropospheric ozone concentration and its impact on agriculture: Indian perspective. EnviroNews Archives. 13(2). Available http://isebindia.com/05_08/07-04-3.html via the INTERNET. Accessed 2009 December 27.

Allen J. 2004 February. Tango in the Atmosphere: Ozone and Climate Change. Available http://www.theozonehole.com/climate.htm via the INTERNET. Accessed 2009 December 10.

Anonymous. 2005. Tropospheric Ozone Lab. Available http://www2.visalia.k12.ca.us/eldiamante/teachers/lmiller/apespdfs/ozone_testing_lab.pdf via the INTERNET. Accessed 2009 November 27.

Anonymous. 2005. Scientific Facts On Air Pollution. Greenfacts.Org Available http://www.greenfacts.org/en/ozone-o3/index.htm via the INTERNET. Accessed 2009 August 28.

Fadeyi M. 2009. Effect Of Ozone On Health In Indoor Environment. Available http://www.prlog.org/10196008-effect-of-ozone-on-health-in-indoor-environment.html via the INTERNET. Accessed 2009 December 9.

Loeb BL. 2008. Ozone Safety. Ozone News. 37(1):pp 16-22. Available http://www.io3a.org/Ozone-Safety-Article.pdf via the INTERNET. Accessed 2009 July 4

Ophardt CE. 2003. Virtual Chembook. Elmhurst College. Available http://www.elmhurst.edu/~chm/vchembook/106Amixture.html via the INTERNET. Accessed 2009 November 27.

Schoeberl MR. 1999. Ozone and Stratospheric Chemistry. EOS Science Plan. Available http://eospso.gsfc.nasa.gov/science_plan/Ch7.pdf via the INTERNET. Accessed 2009 July 4.

Skacel F and others. 2008 January 17. Analyzing ground ozone formation regimes using a principal axis factoring method: A case study of Kladno (Czech republic) industrial area. Atmosfera 21(3): pp 249-263. Available http://www.ejournal.unam.mx/atm/Vol21-3/ATM002100303.pdf via the INTERNET. Accessed 2009 December 10.

Valuntaite V and Girgzdiene R. 2007. Investigation of Ozone Emission and dispersion from Photocopying Machines. Journal of Environmental Engineering and Landscape Management. 15(2): pp 61-67. Available http:/www.jeelm.vgtu.lt/en via the INTERNET. Accessed 2009 July 4.

Weschler, C.J. 2000. Ozone in indoor environments: Concentration and chemistry. Indoor Air 10(4):269-288. Available http://www.ncbi.nlm.nih.gov/pubmed/11089331 via the INTERNET. Accessed 2009 December 9.

APPENDIX A

Raw Data

TIGBAUAN MUNICIPAL HALL

Trial 1

	SC	RH %	O_3 (ppb)
1	1	70	8
2	1	70	8
3	2	70	15
4	1	70	8
5	1	70	8
6	1	70	8
7	2	70	15
8	1	70	10
9	2	70	15
10	1	70	8

Ave: 10.3

Dry bulb: 28 °C
Wet bulb: 24.1 °C
Difference: 3.9

Trial 2

	SC	RH %	O_3 (ppb)
1	1	85	5
2	1	85	5
3	1	85	5
4	1	85	5
5	1	85	5
6	1	85	5
7	1	85	5
8	1	85	5
9	1	85	5
10	1	85	5

Ave: 5

Dry bulb: 26.4 °C
Wet bulb: 24.2°C
Difference: 2.2

Trial 3

	SC	RH %	O_3 (ppb)
1	1	78	6
2	1	78	6
3	1	78	6
4	1	78	6
5	2	78	8
6	2	78	8
7	1	78	6
8	1	78	6
9	1	78	6
10	1	78	6

Ave: 6.4

Dry bulb: 27 °C
Wet bulb: 24 °C
Difference: 3

LAND TRANSPORTATION OFFICE

Trial 1

	SC	RH %	O_3 (ppb)
1	1	65	8
2	1	65	8
3	1	65	8
4	1	65	8
5	1	65	8
6	1	65	8
7	1	65	8
8	1	65	8
9	1	65	8
10	1	65	8

Ave: 8

Dry bulb: 27°C
Wet bulb: 23°C
Difference: 5

Trial 2

	SC	RH %	O_3 (ppb)
1	1	85	5
2	1	85	5
3	1	85	5
4	1	85	5
5	1	85	5
6	1	85	5
7	1	85	5
8	1	85	5
9	1	85	5
10	1	85	5

Ave: 5

Dry bulb: 26°C
Wet bulb: 24°C
Difference: 2

Trial 3

	SC	RH %	O_3 (ppb)
1	1	78	6
2	1	78	6
3	1	78	6
4	1	78	6
5	1	78	6
6	1	78	6
7	1	78	6
8	1	78	6
9	1	78	6
10	1	78	6

Ave: 6

Dry bulb: 26°C
Wet bulb: 23°C
Difference: 3

PSHS-WV

Trial 1

	SC	RH %	O_3 (ppb)
1	2	90	6
2	1	90	5
3	1	90	5
4	2	90	6
5	1	90	5
6	2	90	6
7	1	90	5
8	2	90	6
9	2	90	6
10	1	90	5

Ave: 5.5

Dry bulb: 30.5°C
Wet bulb: 29°C
Difference:1.5

Trial 2

	SC	RH %	O_3 (ppb)
1	1	80	6
2	1	80	6
3	1	80	6
4	2	80	8
5	1	80	6
6	1	80	6
7	1	80	6
8	1	80	6
9	1	80	6
10	1	80	6

Ave: 6.2

Dry bulb: 32°C
Wet bulb: 29°C
Difference: 3

Trial 3

	SC	RH %	O_3 (ppb)
1	1	79	6
2	1	79	6
3	2	79	8
4	1	79	6
5	1	79	6
6	1	79	6
7	1	79	6
8	1	79	6
9	2	79	8
10	1	79	6

Ave: 6.4

Dry bulb: 31°C
Wet bulb: 28°C
Difference: 3

DOST- VI

Trial 1

	SC	RH %	O_3 (ppb)
1	1	79	6
2	1	79	6
3	1	79	6
4	1	79	6
5	1	79	6
6	1	79	6
7	1	79	6
8	1	79	6
9	1	79	6
10	1	79	6

Ave: 6

Dry bulb: 31°C
Wet bulb: 28°C
Difference: 3

Trial 2

	SC	RH %	O_3 (ppb)
1	1	80	6
2	1	80	6
3	1	80	6
4	1	80	6
5	1	80	6
6	1	80	6
7	1	80	6
8	1	80	6
9	1	80	6
10	1	80	6

Ave: 6

Dry bulb: 32°C
Wet bulb: 29°C
Difference: 3

Trial 3

	SC	RH %	O_3 (ppb)
1	1	93	5
2	1	93	5
3	1	93	5
4	1	93	5
5	1	93	5
6	1	93	5
7	1	93	5
8	1	93	5
9	1	93	5
10	1	93	5

Ave: 5

Dry bulb: 30°C
Wet bulb: 29°C
Difference: 1

RAW DATA

Results:

	DOST VI	**Tigbauan**	**LTFRB**	**PSHS-WV**
1st Trial	6	10.3	8	5.5
2nd Trial	6	5	5	6.2
3rd Trial	5	6.4	6	6.4
Ave:	5.666667	7.233333	6.333333	6.033333

	DOST VI	Tigbauan	LTFRB	PSHS-WV
Ave:	5.666667	7.233333	6.333333	6.033333

APPENDIX B

APPENDIX B

Photos

Plate 1. Material used in preparing Schoenbein paper

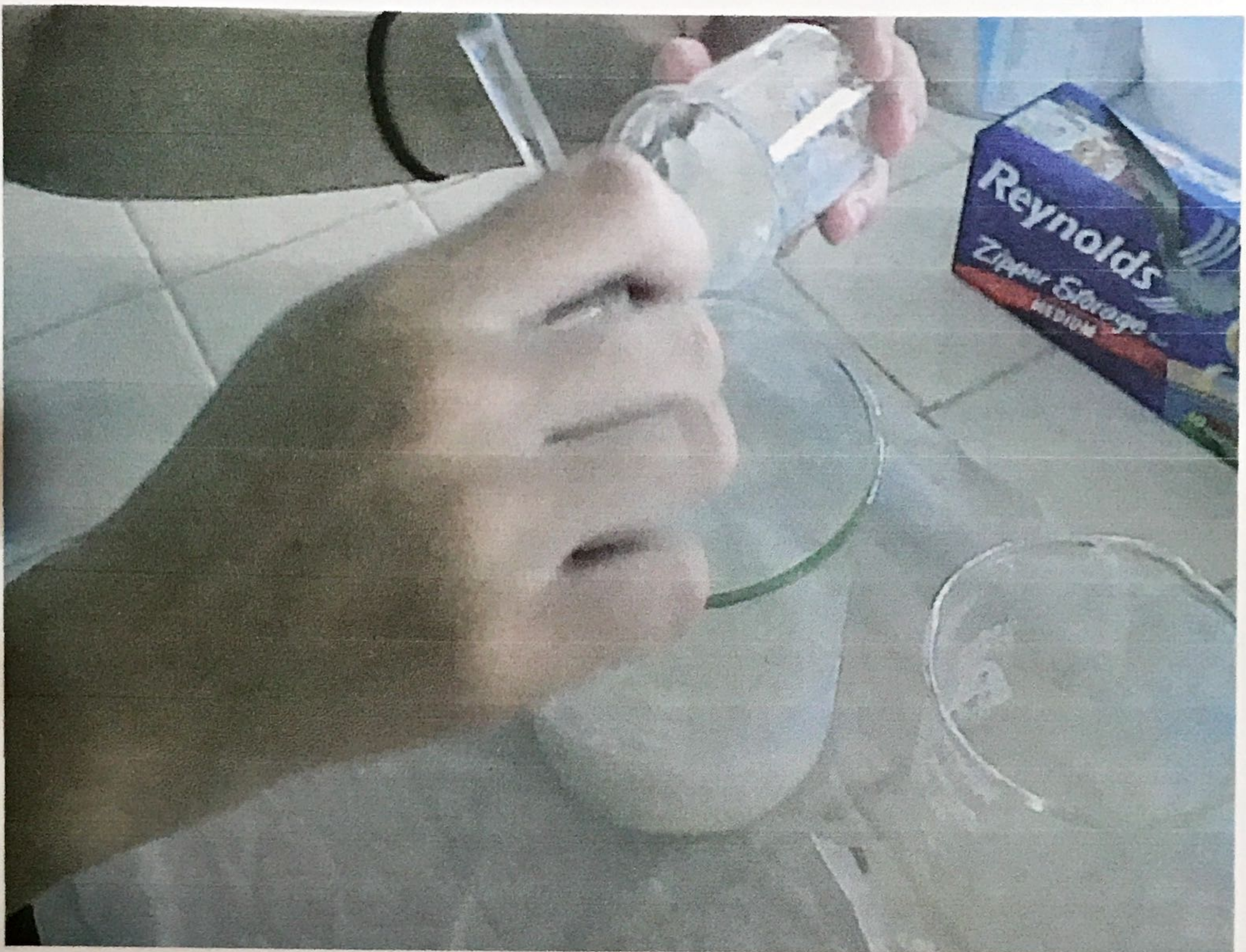

Plate 2. Adding potassium iodide to the cornstarch and water mixture

Plate 3. Heating the Schoenbein mixture using a hotplate

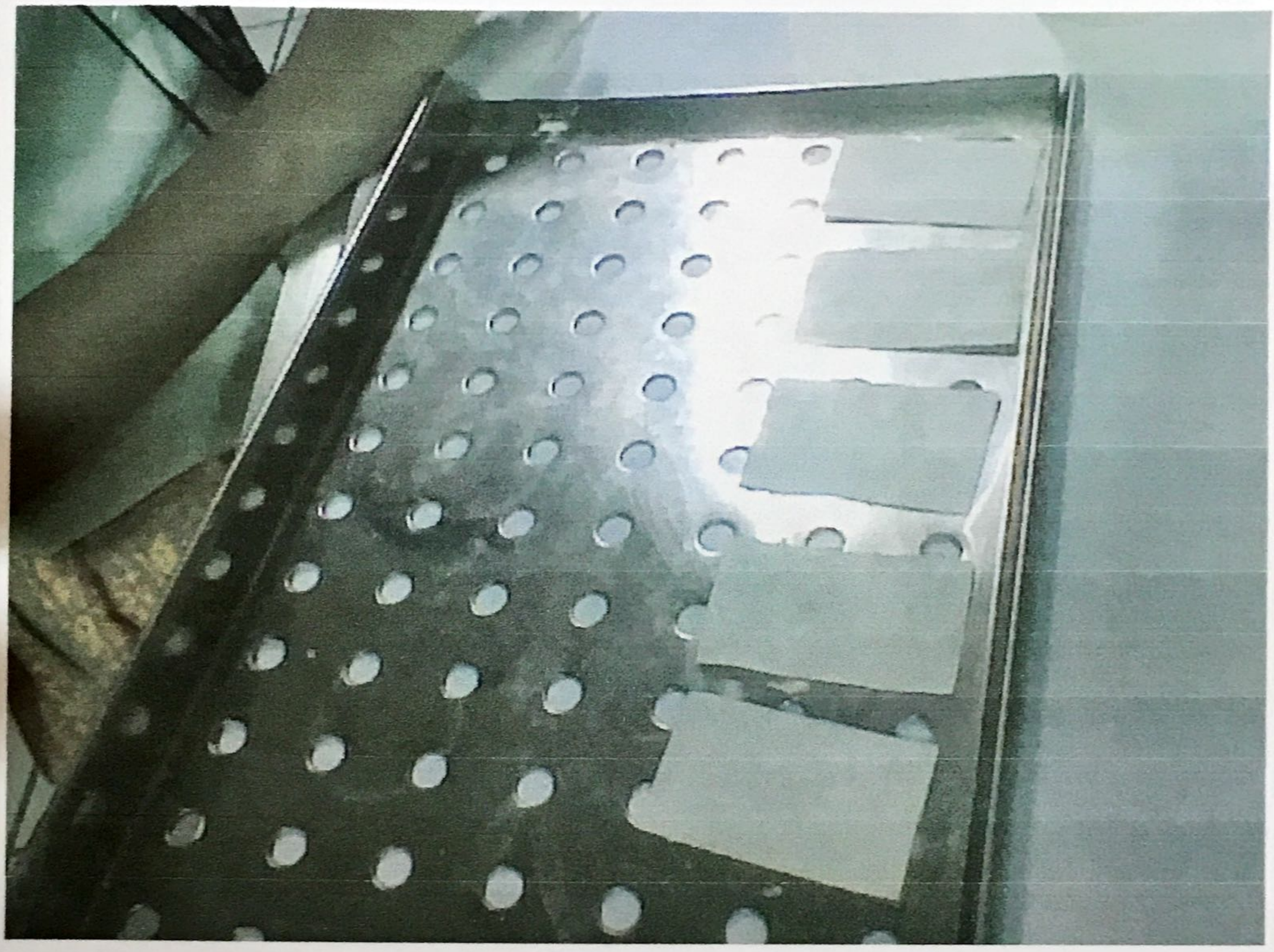

Plate 4. Schoenbein paper to be dried in the oven

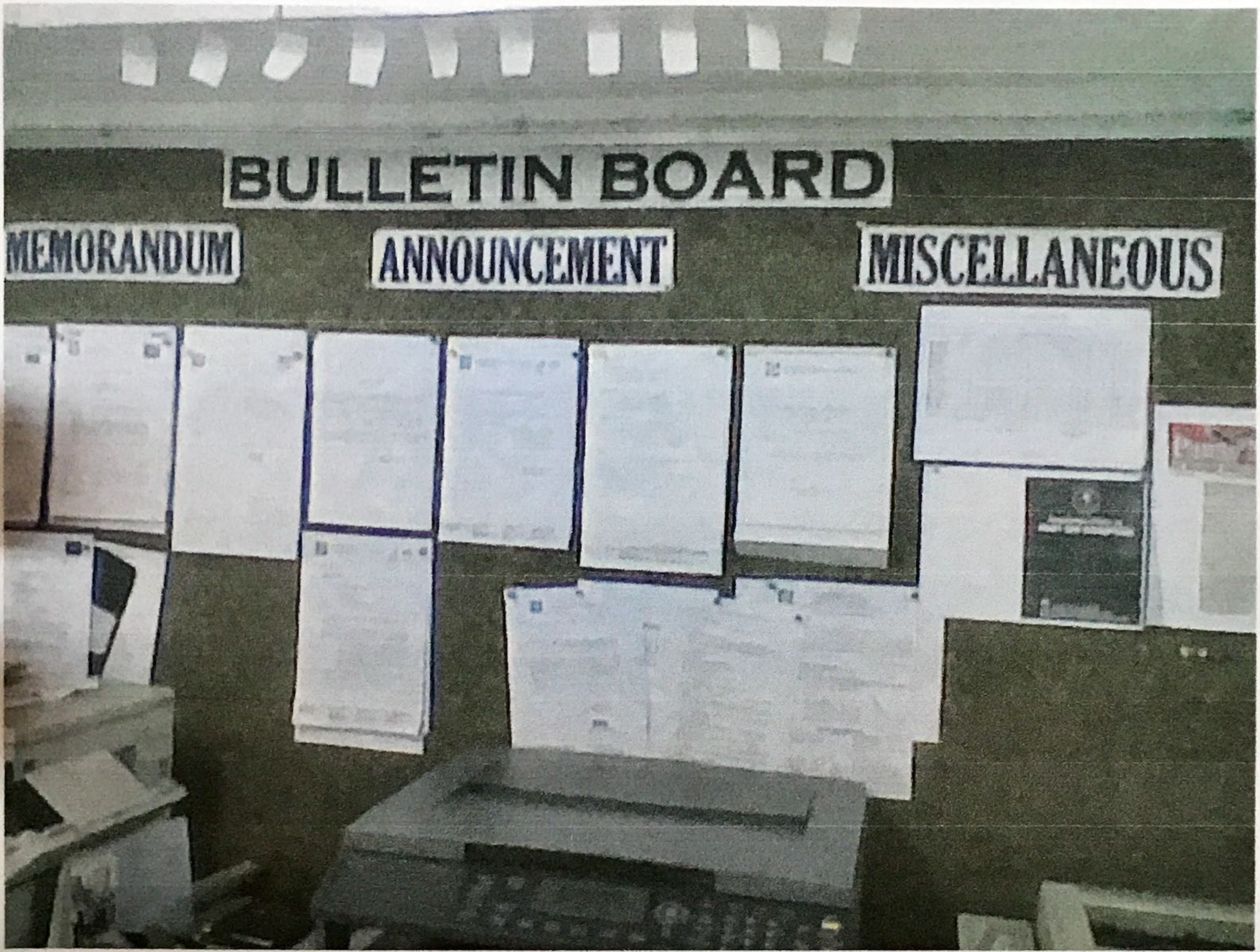

Plate 5. Setup at DOST VI Regional Office

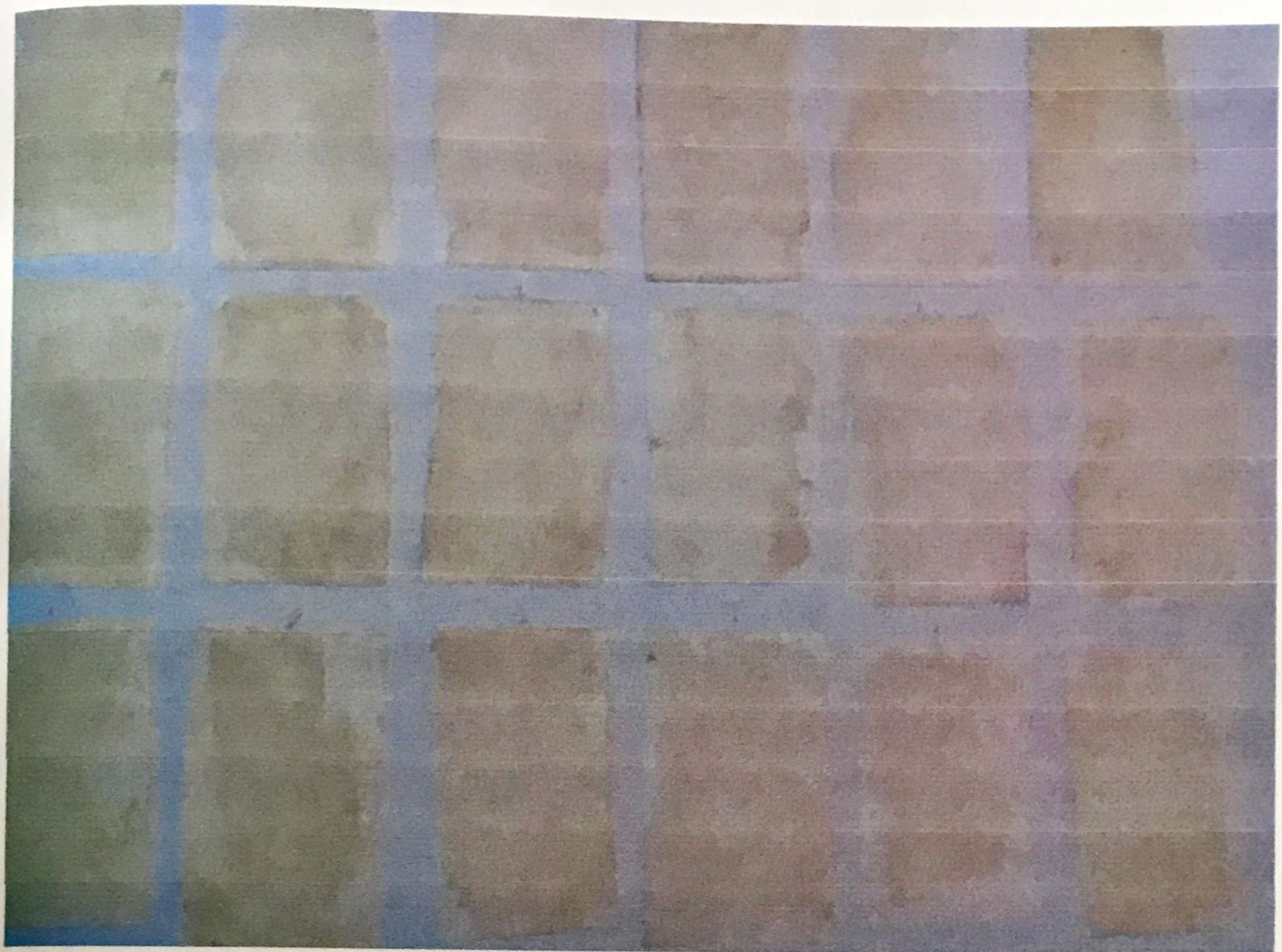

Plate 6. Schoenbein Paper after 8-hr exposure at PSHS WV copy room